Clinical, Cosmetic and Investigational Dentistry

Dovepress

open access to scientific and medical research

Open Access Full Text Article

REVIEW

Factors Influencing Vertical Radicular Fractures in Teeth Supported by Metallic Dental Core: A Scoping Review

Ichraq Oulghazi, Amal El Yamani, Bouabid Morchad

Prosthodontics Department, Mohammed V University, Rabat, Morocco

Correspondence: Ichraq Oulghazi, Prosthodontics department, Mohammed V University, Rabat, 10112, Morocco, Tel +212707163587, Email ichraqoul98@gmail.com

Purpose: The aim of this work is to conduct a literature review to highlight all the parameters involved in sub-prosthetic radicular fractures of teeth supported by metallic dental core.

Materials and Methods: The following research was performed among published studies over the last 10 years in two PubMed/Medline and Scopus and supplemented by manual searching within the bibliographies. The search was restricted to publications in English and French.

Results: Out of the 1464 articles initially identified, 18 studies met our inclusion criteria and were subsequently included in the literature review. These consisted of eight Finite Element Analysis Studies, two Retrospective Studies and one Randomized Controlled Trial. The results of this review show that radicular fractures are influenced by several variables, including predisposition, with maxillary premolars and mandibular molars being the most commonly affected teeth. Intracanal preparation can induce crack formation, leading to localized high stress concentrations. Increased ferrule height to 2 mm significantly enhances dental fracture resistance. Using high modulus of elasticity alloys results in nearly complete stress transmission to dentin due to their limited deformability and absorption capacity. The highest fracture resistance is achieved when posts are sealed using resin-modified glass-ionomer cement. Longer posts may be preferable to prevent vertical fractures. Additionally, occlusal factors, through repetitive stresses, contribute to crack propagation from surface defects, a phenomenon termed fatigue fracture.

Conclusion: These findings have significant implications. Practitioners should be aware of the predisposition of certain teeth, the importance of preserving the ferrule effect, the choice of root post materials, post Cement Material and the role of occlusal forces in managing and preventing vertical root fractures.

Keywords: endodontically treated teeth, root fracture, radicular fracture, tooth fracture, dental restoration failure, biomechanical factor, stress factor, cast post, metal post, post and core technique, dental posts, metallic coronoradicular restoration

Introduction

A vertical root fracture (VRF) is defined as a longitudinal fracture of the root, where the fracture lines run parallel to the long axis. Vertical root fractures (VRFs) typically initiate within the root canal and extend outward toward the root's surface. Studies suggest VRFs occur in 11% to 20% of endodontically treated teeth. While their exact frequency is uncertain, VRFs are commonly encountered in clinical practice, primarily affecting treated teeth, particularly those with or without posts, and are more prevalent in posterior teeth of patients over 40. During the early stages, symptoms of VRFs may be subjective or minimal, posing challenges for diagnosis. As the fracture progresses, patients typically experience discomfort, mild pain, dull pain while chewing, gingival swelling, sensitivity, and localized periodontal probing defects. Radiographic images may reveal bone loss resembling periodontal damage, a fractured root, periradicular radiolucency, widening of the periodontal ligament, and sudden changes in root canal space density or width.[1]

Various factors have been proposed to contribute to vertical root fractures (VRFs) in teeth that have undergone endodontic treatment. These factors include excessive root canal preparation, unnecessary removal of tooth structure

Received: 9 January 2024
Accepted: 11 April 2024
Published: 21 April 2024

during instrumentation, applying excessive force during root canal filling, wedging forces, corrosion and expansion of root canal posts, and intracanal restorations. Other risk factors include a worn occlusal surface and thin root morphology.[1]

Metallic post and core restorations are a widely accepted method to restore endodontically treated teeth with compromised tooth structure. The most common complications associated with post and core restorations are loss of retention (5%), root fracture (3%), and secondary caries lesion (2%).[2]

Radicular fractures are influenced by various parameters, such as the length and width of the post, the ferrule effect, post cement material, and others. Evaluating these parameters is crucial for determining the future prognosis of the tooth.

Therefore, the objective of this study is to conduct a scoping review to highlight all the parameters involved in sub-prosthetic radicular fractures of teeth supported by metallic dental cores.

Materials and Methods

The following research was based on the interrogation of two bibliographic, scientific, and medical databases, with a language restriction limited to French and English, over a period from 2013 to 2023.

PubMed/Medline: 2013–06/2023.

Scopus: 2013–06/2023.

It was then supplemented by manual searching within the bibliographies of pre-selected articles from the initial search.

Keywords

Endodontically treated teeth, root fracture, radicular fracture, tooth fracture, dental restoration failure, biomechanical factor, stress factor, cast post, metal post, post and core technique, dental posts, metallic coronoradicular restoration.

These keywords were combined to formulate the following search equations:

("Endodontically treated teeth") AND (("root fracture") OR ("radicular fracture") OR ("Tooth fracture")) OR ("Dental restoration failure") AND (("biomechanical factor") OR ("Stress factor")) AND (('Cast posts') OR ("Metal post") OR ("Post core technique") OR ('Dental posts') OR ("Metallic coronoradicular restoration"))

AND

(("root fracture") OR ("radicular fracture")) OR ("Dental restoration failure") AND (("Cast posts") OR ("Metal post") OR ("Dental posts") OR ("Metallic coronoradicular restoration"))

Inclusion and Exclusion Criteria

This step involves specifying the criteria for study selection. In this context, inclusion criteria are those that lead to the retention of a study, while exclusion criteria result in the inevitable rejection of the study.

Inclusion criteria: Prospective studies - Retrospective studies -Book chapters - Grey literature- Publications that are neither in French nor in English - Experimental studies

Exclusion criteria: Case serie - Literature reviews - Systematic reviews - Opinion and review articles – Encyclopedias - Animal studies - Studies with titles and/or abstracts that do not match the research question

Selection Strategy is Carried Out in Four Essential Steps

1st Step: Preselection of articles based on their titles.

2nd Step: Provisional inclusion or exclusion of the article based on predefined selection criteria after reading its abstract.

3rd Step: Reading the article in its entirety with definitive inclusion or exclusion based on the criteria.

4th Step: Analysis of the retained articles.

Data Extraction

From the full text of the included articles, the following information is collected: Author names, Publication date, Study type, Number of participants, Study objective, Interventions.

Results

Flowchart

To present the results of our literature review, we have created a flowchart to illustrate the various stages of the research and study selection process leading to the final body of work. (Figure 1) The baseline characteristics of the included studies are shown in Table 1.

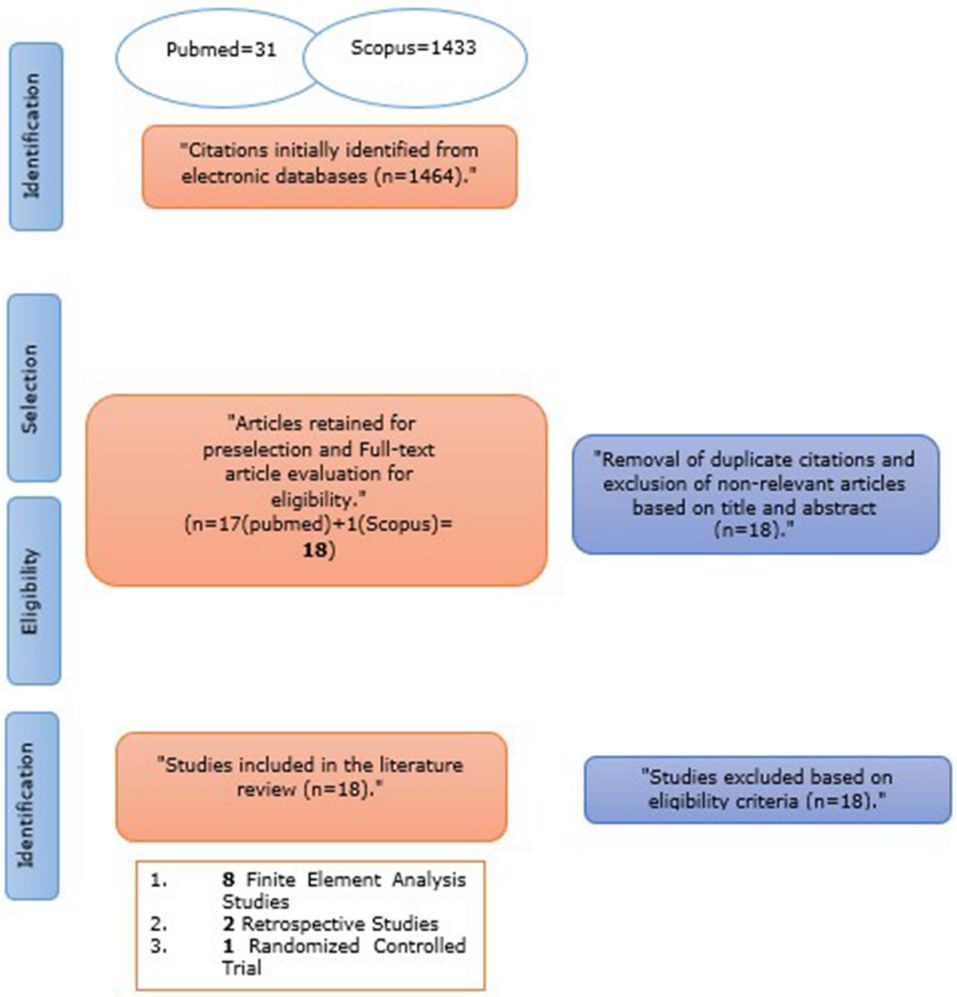

Figure 1 Flow chart of study selection.

Table 1 Characteristics of the Studies Included in the Scoping Review

"Author/ Date/Study Type"	"Number of Samples Studied"	"Objectives"	"Study Protocol"	"Results"
1-M Ona and al. (2013)[3] (Finite Element Analysis Studies)	"Finite element models (FEM) are constructed of a second premolar".	To study the impact of elastic modulus mismatch between dental tissue and root reconstruction materials on radicular fracture mechanisms.	- 3D models of teeth with different restorations (metal and composite). - Tests with and without bonding of the restorations. - Assessment of the risk of dental fracture and restoration debonding.	- Bonded metal restorations have low fracture risk. - Cast post debonding risk is twice as high as fiber posts. - Elastic modulus mismatch contributes to post debonding, possibly increasing radicular fracture risk. - Bonding offers fracture advantages over conventional cementation
2- Torres-Sánchez C. and al.(2013)[4] ("Laboratory Experimental Study")	Forty-two single-rooted premolars.	Measure the fracture resistance of teeth that have undergone endodontic treatment and have been restored with different types of posts based on the materials and cements used.	- Six groups were formed: three with fiberglass posts and three with cast gold posts. - Each group used one of three dental cement types: resin-modified glass ionomer cement, dual-polymerizing resin cement, or chemically active autopolymerizing resin cement. - Metal crowns were applied to all six groups. - Samples underwent compression testing to measure fracture resistance.	- Fiberglass reinforced posts enhanced fracture resistance in treated teeth. - Among the cement types used, resin-modified glass ionomer cement yielded the highest fracture resistance compared to dual-cure resin and autopolymerizing cement.
3- Dejak B. and al.(2013)[5] (Finite Element Analysis Studies)	Thirteen 3D models of upper first incisors.	Evaluate the influence of the ferrule effect, the length of cast metal posts, and fiberglass posts on the resistance of anterior teeth.	- The research investigated tooth models, including intact teeth, those restored with varying lengths of cast metal posts, and fiberglass posts with or without a ferrule effect. - A standardized load of 100 N was applied to the lingual cingulum of the teeth at a 130degree angle. - Specific criteria were used to assess the strength of dental materials such as tissues, ceramics, composites, fiber posts, and cast metal posts. - Contact stresses at the cement-tooth interface were calculated as part of the analysis.	- The ferrule effect significantly decreases stresses in teeth restored with posts. - Rigid post materials aid in reducing stress in incisors. - Teeth with 10 mm posts exhibit double the fracture resistance of those with 5 mm posts. - Post length does not impact tooth resistance in the presence of a 2 mm ferrule.

https://doi.org/10.2147/CCIDE.S458697 DovePress

4- Barcellos RR. and al.(2013)[6] (Laboratory Experimental Study)	Seventy upper canines	To study the influence of the post system and the amount of remaining radicular tissue on the fracture resistance of endodontically treated teeth.	- The sample was categorized into seven groups, considering the post type (fiber, fiber with resin composite overlay, or nickel-chrome NiCr) and remaining radicular tissue thickness (1 mm or 2 mm). - Restored teeth were subjected to loads in a controlled chewing simulator. - Fracture resistance tests were performed on the samples.	- Fiber posts coated in resin composite showed the highest fracture resistance, followed closely by basic fiber posts and cast posts with comparable resistance levels. - Improved postcanal adaptation significantly enhances frictional retention and boosts fracture resistance.
5- Rippe MP. and al.(2014)[7] (Laboratory Experimental Study)	Eighty single-rooted human teeth.	Assessing the impact of canal preparation type, intraradicular post, and fatigue loading on root fracture resistance.	- The sample was divided into 8 groups based on canal preparation method, post type, and the application of mechanical stress. - Canal preparation was performed for a 10 mm post. - Mechanical stress was applied to specific groups. - Fracture resistance testing was conducted until failure.	- Dental canal preparation did not significantly impact root fracture resistance. - Post type influenced resistance and fracture mode, with fractures occurring at high loads. - Cast posts showed greater fracture resistance than fiber posts under oblique loading. - Cast posts may incur irreparable apical fractures under high stress, while fiber posts typically sustain reparable coronal fractures.

(*Continued*)

https://doi.org/10.2147/CCIDE.S458697

Table 1 (Continued).

"Author/ Date/Study Type"	"Number of Samples Studied"	"Objectives"	"Study Protocol"	"Results"
6- Madfa AA. and al. (2014)[8] (Finite Element Analysis Studies)	10 (3D) models of an adult maxillary central incisor.	The objective of this study was to analyze and compare the stability of two dental post forms (parallel-sided and tapered) made from different materials (titanium, zirconia, carbon fiber, and glass fiber) using the finite element method.	- An oblique load of 100 N was applied to each 3D model. - Analyses were conducted along the center of the post, at the crown/cement/inlay core interface, and at the inlay core/cement/ dentin interface, and the averages were calculated	- Tapered posts resulted in significantly higher stresses, especially along the post center, compared to parallel-sided posts. - Stainless steel posts showed the highest stress levels, followed by zirconia, titanium, glass fiber, and carbon fiber posts.
7- Kainose K. and al. (2014)[9] (Finite Element Analysis Studies)	Three-dimensional mathematical models of a mandibular premolar tooth.	Examine the distribution of interfacial stresses in teeth restored with different post lengths and crown heights	- Replacement of certain parts of the dental structure with ceramic crowns of three different crown heights (6, 7, and 8 mm) (lack of ferrule). - Either fiberglass posts or NiCr alloy metal posts with four different post lengths (4, 6, 8, and 10 mm) were used. - Linear finite element analysis to calculate equivalent and shear stresses at the interfaces under specific loads.	- The presence of a cervical ferrule eliminates the influence of post length and post core material properties on both fracture resistance and stress distribution in restored teeth. - Without a cervical ferrule, however, post material and length significantly affect stress distribution. - In models with metallic posts, shorter post lengths lead to increased stress levels towards the apex. - Shear stress at the post and canal housing interface was mainly generated in the cast post and increased with decreasing post length. - There is a risk of cast post debonding, especially if it is shorter.
8- Oyar P. (2014)[10] (Finite Element Analysis Studies)	A mandibular second premolar was scanned using computer-assisted tomography to obtain 1 mm-thick slices of dental tissue, and the data was combined with manual data to create three-dimensional finite element models using computer-aided design software.	Determine which combinations of post core cement offer the most favorable stress distribution under load.	- Three-dimensional tooth models were created to simulate different materials for metal-ceramic crowns (nickel-chrome, goldpalladium), cast posts (Ti, NiCr, AuPd), and cements (glass ionomer, composite resin, zinc phosphate, polycarboxylate, Panavia). A chewing force of 400 N was then applied to the occlusal surface.	- Employing a post material with lower elasticity modulus alongside a cement with higher elasticity modulus led to decreased deformation in the residual root, bonding material, and post, as well as a reduction in post stress. - The combination of NiCr ceramic-metal crown / AuPd inlay core / zinc phosphate or Panavia cement may be advantageous for post and core restorations.

https://doi.org/10.2147/CCIDE.S458697 DovePress

9-Sugaya T. and al. (2015)[11] (Retrospective Study)	"304 fractured teeth".	"Compare dental root fractures in the cervical and apical regions to understand the causes and risks".	- A retrospective study of patient records with vertical root fractures. - Data collection based on age, gender, tooth type, fracture location, fracture site, and the presence of posts. - Classification of fractures as cervical, middle, or apical. - Evaluation of the fracture condition based on post length.	- Cervical and apical fractures occur with similar frequency, while median fractures are rare. - Apical fractures are only observed in the first maxillary and mandibular premolars, all on the buccal/lingual side. - Post debonding poses a significant risk factor for fractures originating from the cervical region. - Circular root canals distribute occlusal force evenly around the canal wall, while oval root canals concentrate stress on the buccal and lingual sides. - There is no association between post length and fractures originating from the cervical region. - Longer posts are associated with fewer apical fractures.
10- Uzun İ. and al.(2015)[12] (Laboratory Experimental Study)	Seventy mandibular premolars with oval root canals were dissected. Fourteen teeth were used as the control group.	The objective of this study was to evaluate the effects of root canal preparations with circular and oval burs and the placement of oval and circular posts on the fracture resistance of roots with oval canals.	- The root canals were filled, and the samples were randomly divided into 4 experimental groups. - A fracture resistance test was conducted on each specimen, and the data were statistically analyzed.	- Oval posts did not provide higher fracture resistance to endodontically treated roots with oval canals compared to circular posts
11- Samran A. and al. (2015)[13] (In Vitro Experimental Study)	Seventy-two extracted human mandibular premolars.	The objective is to compare the effect of ferrule placement on the fracture resistance of mandibular premolars that have undergone endodontic treatment.	6 groups were formed: - Control Group: Endodontically treated teeth without endodontic posts or crowns - Teeth with a 2mm circumferential ferrule - Teeth with a 2mm buccal ferrule - Teeth with a 2mm lingual ferrule - Teeth with both 2mm buccal and lingual ferrules - Posts were cemented with a self-adhesive resin cement - NiCr crowns were cemented on each prepared tooth. - All samples were subjected to a quasistatic load at a 30° angle in a universal testing machine until fracture.	- No statistically significant differences were observed between the groups, except for the differences between the control group and the groups of teeth with a 2mm lingual ferrule and those with both 2mm buccal and lingual ferrules. - The ferrule placement had no significant effect on the fracture resistance of mandibular premolars that had undergone endodontic treatment.

(*Continued*)

https://doi.org/10.2147/CCIDE.S458697 DovePress

Table 1 (Continued).

"Author/ Date/Study Type"	"Number of Samples Studied"	"Objectives"	"Study Protocol"	"Results"
12- Abdulmunem A. Dabbagh and al. (2016)[14] (Finite Element Analysis Studies)	Sixty extracted maxillary incisors collected from the dental and orthodontic clinics of the University of Malaya.	- To investigate the impact of post type (titanium, fiber, and stainless steel) and cement type (zinc phosphate and composite resin) on the fracture resistance and failure mode of endodontically treated teeth.	- The teeth were randomly restored using three types of dental posts: titanium, fiber, or stainless steel. - Two types of luting cements were used: zinc oxyphosphate or composite resin. - Restored teeth were subjected to thermocycling cycles. - Samples were loaded at a 135degree angle until failures were observed.	- Zinc oxyphosphate cement showed higher fracture resistance. - The choice of post material and luting cement significantly impacted fracture resistance and failure mode in restored teeth after endodontic treatment.
13- Liao WC. and al. (2017)[1] (Retrospective cohort study)	A total of 65 teeth with 68 vertically fractured roots in 58 Chinese patients were studied.	The clinical and radiographic features of vertical root fractures.	- Clinical examination records and radiographic images were thoroughly reviewed. - Clinical features such as patients' gender, age, the number of teeth with vertical root fractures, periodontal probing depth, the presence of prostheses, and the overall condition of the dentition were assessed.	- Vertical root fractures were more common in the mesial roots of mandibular molars. - Teeth with vertical root fractures generally exhibited a periodontal probing depth of >5 mm, and they were often associated with dental prostheses and relatively intact dentition. - Radiographic characteristics of teeth with vertical root fractures were related to previous endodontic treatments, periodontal bone loss, apical bone loss, and widening of the periodontal ligament.
14- Teshigawara D. and al. (2019)[15] (Finite Element Analysis Studies)	A dental model was created and then divided into 4517 sections using eight-noded hexahedral elements.	Analyzing the failure processes of the cement in teeth restored with posts and determining how the elastic properties of the posts affect these failure processes.	- The finite element analysis focused on the sequential failure of adhesion between dentin and cement. - The penalty function method was used to analyze the stresses at each step of the adhesion conditions. - Failure models of adhesion and the stress distribution in dentin under the load of different post materials were observed.	- With the use of a metal post, bonding material failure initially occurred at the palatal edge, extending along the crownpost interface towards the vestibular side. - Stress concentration was noted at the interface areas, correlating with adhesive failure. - This stress concentration may lead to cracks in these areas, resulting in vertical root fractures with metal posts and horizontal fractures with resin posts. - Local stress concentrations are influenced not only by the post material but also by the quality and bonding conditions to dentin.

https://doi.org/10.2147/CCIDE.S458697 DovePress

15- Sarkis-Onofre R. and al.(2020)[16] (Randomized controlled study)	A total of 119 patients and 183 posts (72 cast metal posts and 111 fiber posts) were analyzed.	Evaluate the survival and success of fiber posts compared to cast metal posts in teeth without ferrules	- The teeth were randomly divided into the two groups. - All teeth were restored with individual ceramic-metal crowns. - Statistical analysis was conducted to evaluate post success and survival. - Annual failure rates were calculated for both post types after five years. - Results were analyzed taking into account the type of failure and its location.	- Cast metal posts had an annual failure rate of 1.2%, while fiber posts had an annual failure rate of 1.7%. - The majority of failures occurred in posterior teeth (primarily premolars) with 16 out of 23, including 10 root fractures and 5 post dislodgements. - No significant difference between fiber posts and metal posts regarding the risk of root fracture was observed. - Both types of posts demonstrated similar clinical performance when used with single crowns.
16- Veeraganta SK. and al. (2020)[17] (In Vitro Experimental Study)	Sixty-four first mandibular premolars, which had undergone endodontic treatment, were divided into 8 test groups.	The aim of this in vitro study was to assess the influence of post material and diameter on the fracture resistance of endodontically treated mandibular premolars.	Grouping: Samples were divided into 8 groups based on wall count, post material, and post diameter. Sample prep: Posts were cemented, and resin cores with a 2mm ferrule were created. Crowns: CoCr crowns were cemented with glass ionomer. Cycles: Specimens underwent 1,200,000 chewing cycles and thermocycling. Testing: Specimens were loaded until fracture at a 30° angle.	- Post material and post diameter had a significant influence on fracture resistance. - When smaller diameter posts are used, a titanium system may be more suitable than a fiber post because it demonstrated higher fracture resistance. - Beyond a 2 mm ferrule, the amount of tooth substance loss had no influence on the fracture resistance of endodontically treated teeth restored with posts.
17- Iemsaengchairat R. and al. (2021)[18] (In Vitro Experimental Study)	Forty-eight single-rooted mandibular premolars with single root canals were endodontically treated.	To assess the fracture resistance and failure characteristics of simulated thin-walled endodontically treated teeth restored with various techniques.	- The roots were randomly divided into four groups of 12 roots, based on the post reconstruction techniques used: composite post (CP), multiple fibers (FP), anatomical CAD/CAM post (AP), and cast metal post (MP). - All specimens underwent thermocycling and were subjected to axial compression until failure at a 45degree angle.	- The group with a cast post provided the highest fracture load. - Cast posts provided the highest fracture resistance for the reconstruction of thin-walled endodontically treated teeth without ferrules.

(*Continued*)

https://doi.org/10.2147/CCIDE.S458697

Table 1 (Continued).

"Author/ Date/Study Type"	"Number of Samples Studied"	"Objectives"	"Study Protocol"	"Results"
18- Mosharaf R. and al. (2023)[19] (Finite Element Analysis Studies)	A 3D scan of a central incisor	To study the effect of the ferrule height-to-crown ratio on the strength of maxillary anterior central teeth using finite element analysis.	- 3D scan of a maxillary central incisor. - Application of 300 N load at 135degree angle to tooth model, horizontally and vertically. - Ferrule height variation on palatal surface from 5% to 25%, with buccal surface at 50%. - Inlay core length variation in model to 11, 13 and 15 mm.	- Increasing the ferrule/crown ratio resulted in elevated stress and strain distribution within the dental model, while decreasing within the post itself. - Augmenting the cervical ferrule ratio enhances dental fracture resistance against applied forces. - Elevating the ferrule height to 2 mm significantly boosts dental fracture resistance. - The synergistic impact of ferrule height and post length suggests that in the presence of a high residual coronal cervical height, a shorter post length may lead to successful treatments.

Discussion

The main objective of our review was to first understand vertical root fractures in terms of diagnosis, dental predispositions, and all the parameters influencing sub-prosthetic root fractures in teeth with cast metal posts. Various factors associated with root fracture include intracanal preparation, ferrule effect, characteristics of the root post (elastic modulus, length, diameter, and clinical situation), inlay-core assembly materials, and occlusal forces.

Diagnosis

The diagnosis of vertical root fractures is based on the triad: subjective, objective, and radiographic evaluation. From the retrospective cohort by Wan-Chuen Liao and al., subjective or objective clinical symptoms and signs of root fractures may be absent or minimal in the early stages, making precise diagnosis of root fractures challenging.[1] As root fracture exacerbation develops, patients often suffer from discomfort, mild pain near the fractured tooth, dull pain during chewing, gingival swelling with a fistula, sensitivity to percussion and palpation, and localized deep periodontal probing defects. Radiographic images can indicate bone loss and bone defects resembling periodontal destruction with a fractured root, periradicular radiolucency, and widening of the periodontal ligament space.[1]

Dental Predisposition

According to the study by Sarkis-Onofre R. and al. and Cohen S. and al., the most commonly affected teeth are maxillary premolars and mandibular molars.[16,20] According to Wan-chuen et al, mandibular first molars followed by maxillary second premolars and maxillary central incisors are the teeth most predisposed to vertical root fracture, whether or not they have undergone endodontic treatment. The roots most likely to fracture are those with narrow mesiodistal diameters and a thin, flat morphology. The root depression of the mesial root of mandibular molars and the buccal root of bifurcated maxillary premolars presents an anatomical entity that may predispose to fractures and root perforations in cases of excessive dentin removal. These areas should be considered "danger zones".[1]

All studies, including finite element studies and experimental studies, have taken this predisposition into account when selecting the test samples.

Intracanal Preparation

According to Rippe MP. and al., manual canal preparation seems to have induced irregularities, cracks, and more frequent wear on the cervical dentin compared to rotary canal preparation. Prosthetic preparation does not seem to eliminate these irregularities, especially when using a fiber post, which results in a higher concentration of stress in the cervical and middle thirds. These cracks can become areas of high stress concentration when forces are applied during restorative procedures or due to occlusal stresses, evolving into fractures over time.[7]

Ferrule Effect

The ferrule effect is the circumferential portion of the prosthetic crown that rests on the cervical dentin, providing the gripping and protection of the tooth. It is considered as the area of remaining dentin at the cervical margin.

According to a finite element study conducted by Dejak B. and al., they demonstrated that the ferrule effect has a critical influence on reducing stress in anterior teeth restored with metal posts.[8]

According to a finite element study by Mosharaf R. and al., increasing the height of the ferrule to 2 mm significantly increases dental fracture resistance. In incisors, retaining coronal dentin on the palatal side doubles their fracture resistance. In a three-year clinical follow-up study, only 6.67% of incisors restored with 2 mm ferrule posts were damaged, while the rate for teeth without ferrule reached 26.20%.[19] However, in the study by Samran A. and al. conducted on mandibular premolars, the specific location of the ferrule had no significant effect on fracture resistance under the study's conditions.[13]

According to Iemsaengchairat R. and al., metal inlay-cores provided the highest fracture resistance for the reconstruction of thin walls in endodontically treated teeth without a ferrule.[18]

Ferrule effect can improve resistance to occlusal forces applied to the tooth. It also reduces the forces applied to the tooth, including shear or bending moments during post placement, contributing to improved crown marginal fit. Ferrule is a key protective factor in preventing root fractures.

Root Posts and Tooth Position

According to the study by Dejak B and al. on 3D central incisors, post length has a minor effect on stress levels in dental structures.[5]

However, according to the study by Kainose K., stress in cast metal posts in mandibular premolars is primarily generated in the end of the post, and this increases with decreasing post length.[9]

The study by Sugaya T. found no association between post length and fractures originating in the cervical region, and there were fewer fractures originating from the apical region with longer posts. Thus, longer posts may be preferable to prevent vertical fractures.[11] These findings are consistent with the study by Misharaf R. and al., which indicates that a reduced post length reduces stress in the cervical region of the tooth and increases stress at the post's end.[19] An interplay exists between the height of the ferrule and the post length, and in the presence of high residual coronal height, a shorter post length might be feasible.

According to the study by Kainose K. and al., in the presence of cervical encirclement, post length and the mechanical properties of post and core materials do not affect fracture resistance and stress distribution in the restored tooth. However, in the absence of cervical encirclement, materials and post length significantly affect stress distribution in the restored tooth. The metallic post model produced lower shear stress at the interface in the cervical area than the fiber post model. However, shear stress at the post and intracanal housing interface was primarily generated in the cast post and increased with decreasing post length. This raises the risk of cast post debonding, especially if the post is shorter. Fiber post models produced lower stress at the root surface, and the effect of post length in this case was less pronounced.[9]

Vertical fractures in the cervical region can occur at the vestibular/lingual and mesial/distal sites, while fractures originating in the apical region were found at the vestibular/lingual location.[11]

According to the study by Veeraganta S. K. and al., larger-diameter posts exhibited greater fracture resistance than smaller-diameter posts, regardless of post material or remaining dental substance. However, using thinner posts has been recommended, as it preserves more radicular dentin, reinforcing the dental structure and enhancing fracture resistance. It is also suggested to limit post diameter to less than 50% of root diameter and preserve dentin as much as possible.[17]

The study by Uzun İ. and al. found that oval posts did not increase fracture resistance in premolars with oval canals compared to circular posts.[12]

According to the study by Ona M. and al., using high modulus of elasticity alloys leads to nearly complete transmission of stresses to dentin due to the limited deformability and absorption capacity associated with a high modulus of elasticity. However, reducing the modulus of elasticity of the post material increased stress on the root surface in anterior teeth subjected to bending.[3]

The study by Madfa AA. and al. conducted on 3D models of maxillary central incisors observed the highest stresses in stainless steel posts, followed by zirconia and titanium posts compared to fiberglass posts.[8] These findings are consistent with the studies by Rippe MP and al., the study by Oyar P and the study by Torres-Sánchez C and al. conducted on single-rooted premolars.[4,7,10]

Fractures Occurring Due to the Use of Glass Fiber or Quartz Posts were Repairable, unlike fractures resulting from Zirconia or Titanium posts, which were irreparable. This could explain why glass and carbon fiber posts exhibited a higher average von Mises stress at the crown-cement/post interface than stainless steel, zirconia, and titanium posts. This concentration of high stresses in stainless steel, zirconia, and titanium posts could potentially lead to post debonding from radicular walls.[8]

According to the study by Veeraganta SK and al., titanium posts on mandibular premolars showed statistically higher fracture resistance than fiberglass posts.[17]

Fractures with a guarded prognosis occurred only under loads greater than physiological force values. This implies that these fractures may not occur under physiological loads.[7] This is in line with the study by Barcellos RR and al.[6]

Indeed, posts with higher modulus of elasticity amplify stresses within the post itself and reduce stress distribution in radicular dentin. Posts with an elastic modulus similar to dentin formed a mechanically homogeneous unit (monobloc) with better biomechanical performance.[6,7]

According to the study by Dejak B and al. on 3D central incisors, using rigid materials for posts results in reduced stresses in dental tissues. Teeth restored with cast posts need to demonstrate higher fracture resistance than teeth with fiber posts.[5]

Finally, according to the randomized controlled trial by Sarkis-Onofre R. and al., cast metal posts had an annual failure rate of 1.2%, while fiberglass posts had an annual failure rate of 1.7%.[16]

Post Cement Material

As per the study by Oyar P.[10] and al., using a post material with a lower modulus of elasticity and a cement material with a higher modulus of elasticity reduced deformation in the residual root, cement, and post, as well as reduced stress in the post. The combination of ceramic-metal crown/Ni-Cr (nickel-chrome) post/Au-Pd (gold-palladium) zinc phosphate or Panavia cement could be favorable for post and core restorations.[10]

According to the study by Torres-Sánchez C., the highest fracture resistance was observed in the group with posts sealed using resin-modified glass-ionomer cement.[4]

According to Abdulmunem M. and al., using zinc phosphate cement offered relatively higher fracture resistance. Composite resin as a luting cement resulted in more restorable failure modes. However, the adhesive technique makes cleaning the smear layer from the root canal space and removing moisture from the root challenging.[14] Adhesion is less certain in the radicular than in the coronal region, primarily due to structural dentin changes and a decrease in the number of dentinal tubules. Therefore, it is best not to attempt bonding more than 5 to 7mm into the root canal.[21]

According to Veeraganta S. K. and al.[17] customizing the post increases its adaptation to root walls and reduces resin thickness. Closer contact between the cement type and dentin is also crucial for enhancing post frictional retention, with frictional retention being directly proportional to the contact surface (larger contact surfaces result in better retention).[17]

The sealing technique can affect the fracture resistance of restored teeth. Residues in the post space, bubbles in the cement layer, and excessive seating pressure can lead to stress concentration in the root and predispose it to fracture.

Occlusal Loads

Cast metal posts have a high modulus of elasticity, and when subjected to occlusal forces, they exert forces against radicular dentin walls, which have a lower modulus of elasticity, increasing the risk of coronoradicular fracture.[6]

Bruxism imposes significant non-physiological mechanical stresses but does not seem to be as determinant in causing radicular fractures as it might be for coronal cracks. However, it remains a risk factor that could increase cases of vertical fracture.[20,22]

Occlusal factors, in the form of repetitive stresses, are responsible for propagating cracks from surface defects. This is known as fatigue fracture.[23]

Conclusion

Understanding vertical radicular fractures in teeth supporting cast metal post restorations relies on a thorough diagnosis, encompassing subjective, objective, and radiographic evaluations. These findings have significant implications. Practitioners should be aware of the predisposition of certain teeth, the importance of preserving the ferrule effect, the choice of root post materials, and the role of occlusal forces in managing and preventing vertical root fractures. This knowledge can guide clinical decision-making, leading to more effective and tailored treatment approaches, ultimately benefiting patients' oral health and long-term outcomes.

Disclosure

The authors report no conflicts of interest in this work.

References

1. Liao WC, Tsai YL, Wang CY. Clinical and Radiographic Characteristics of Vertical Root Fractures in Endodontically and Nonendodontically Treated Teeth. *J Endod*. 2017;43(5):687–693. doi:10.1016/j.joen.2016.12.009
2. Goodacre C, Bernal G, Runcharassaeng K, Kan J. Clinical Complications in Fixed Prosthodontics. *J Prosthetic Dent*. 2003;90(1):31–41. doi:10.1016/S0022-3913(03)00214-2
3. Ona M, Wakabayashi N, Yamazaki T, Takaichi A, Igarashi Y. The influence of elastic modulus mismatch between tooth and post and core restorations on root fracture. *Int Endod J*. 2013;46(1):47–52. doi:10.1111/j.1365-2591.2012.02092.x
4. Torres-Sánchez C, Montoya-Salazar V, Córdoba P, et al. Fracture resistance of endodontically treated teeth restored with glass fiber reinforced posts and cast gold post and cores cemented with three cements. *J Prosthet Dent*. 2013;110(2):127–133. doi:10.1016/S0022-3913(13)60352-2
5. Dejak B, Młotkowski A. The influence of ferrule effect and length of cast and FRC posts on the stresses in anterior teeth. *Dent Mater*. 2013;29(9):e227–37. doi:10.1016/j.dental.2013.06.002
6. Barcellos RR, Correia DP, Farina AP, Mesquita MF, Ferraz CC, Cecchin D. Fracture resistance of endodontically treated teeth restored with intra-radicular post: the effects of post system and dentine thickness. *J Biomech*. 2013;18(15):2572–2577. doi:10.1016/j.jbiomech.2013.08.016
7. Rippe MP, Santini MF, Bier CAS, Baldissara P, Valandro LF. Effect of root canal preparation, type of endodontic post and mechanical cycling on root fracture strength. *J Appl Oral Sci Rev FOB*. 2014;22(3).
8. Madfa AA, Kadir MRA, Kashani J, et al. Stress distributions in maxillary central incisors restored with various types of post materials and designs. *Med Eng Phys*. 2014;36(7):962. doi:10.1016/j.medengphy.2014.03.018
9. Kainose K, Nakajima M, Foxton R, Wakabayashi N, Tagami J. Stress distribution in root filled teeth restored with various post and core techniques: effect of post length and crown height. *Int Endod J*. 2015;48(11):1023–1032. doi:10.1111/iej.12397
10. Oyar P. The effects of post-core and crown material and luting agents on stress distribution in tooth restorations. *J Prosthet Dent*. 2014;112(2):211–219. doi:10.1016/j.prosdent.2013.10.024
11. Sugaya T, Nakatsuka M, Inoue K, et al. Comparison of fracture sites and post lengths in longitudinal root fractures. *J Endod*. 2015;41(2):159–163. doi:10.1016/j.joen.2014.09.017
12. Uzun İ, Arslan H, Doğanay E, Güler B, Keskin C, Çapar ID. Fracture resistance of endodontically treated roots with oval canals restored with oval and circular posts. *J Endod*. 2015;41(4):539–543. doi:10.1016/j.joen.2014.11.009
13. Samran A, Al-Afandi M, Kadour JA, Kern M. Effect of ferrule location on the fracture resistance of crowned mandibular premolars: an in vitro study. *J Prosthet Dent*. 2015;114(1):86–91. doi:10.1016/j.prosdent.2014.12.014
14. Abdulmunem M, Dabbagh A, Naderi S, Talaei Zadeh M. Evaluation of the effect of dental cements on fracture resistance and fracture mode of teeth restored with various dental posts: a finite element analysis. *J Eur Ceram Soc*. 2016;36(9):2213–2221. doi:10.1016/j.jeurceramsoc.2016.01.021
15. Teshigawara D, Ino T, Otsuka H, Isogai T, Fujisawa M. Influence of elastic modulus mismatch between dentin and post-and-core on sequential bonding failure. *J Prosthodont Res*. 2019;63(2):227–231. doi:10.1016/j.jpor.2018.12.003
16. Sarkis-Onofre R, Amaral Pinheiro H, Poletto-Neto V, Bergoli CD, Cenci MS, Pereira-Cenci T. Randomized controlled trial comparing glass fiber posts and cast metal posts. *J Dent*. 2020;96:103334. doi:10.1016/j.jdent.2020.103334
17. Veeraganta SK, Samran A, Wille S, Kern M. Influence of post material, post diameter, and substance loss on the fracture resistance of endodontically treated teeth: a laboratory study. *J Prosthet Dent*. 2020;124(6):739.e1–739.e7. doi:10.1016/j.prosdent.2020.05.002
18. Iemsaengchairat R, Aksorn Muang J. Fracture resistance of thin wall endodontically treated teeth without ferrules restored with various techniques. *J Esthet Restor Dent off Publ Am Acad Esthet Dent Al*. 2022;34(4):670–679. doi:10.1111/jerd.12859
19. Mosharaf R, Abolhasani M, Fathi AH, Rajabi A. The Effect of Ferrule/Crown Ratio and Post Length on the Applied Stress and Strain Distribution to the Endodontically Treated Maxillary Central Teeth: a Finite Element Analysis. *Front Dent*. 2023;20:16. doi:10.18502/fid.v20i16.12686
20. Cohen S, Berman LH, Blanco L, Bakland L, Kim JS. A demographic analysis of vertical root fractures. *J Endod*. 2006;32(12):1160–1163. doi:10.1016/j.joen.2006.07.008
21. Brousseaud J Reconstitutions corono-radiculaires: vers un changement de paradigme ? Id Webformation; 2023. Available from: https://www.idwebformation.fr/reconstitutions-corono-radiculaires-vers-un-changement-de-paradigme/. Accessed April 12, 2024.
22. Yokoyama K, Matsumoto K, Kinoshita J, Sasaki H, Komori T. Treatment of maxillary molars with vertical fractures. *Endod Dent Traumatol*. 1998;14(6):287–289. doi:10.1111/j.1600-9657.1998.tb00855.x
23. Bronnec F. Vertical root cracks and fractures. *Rev Odont Stomat*. 2009;38:279–294.